https://doi.org/10.54589/aol.37/3/237

Mandibular size as a predictor of vertical dimension of occlusion based on cephalometric analysis

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ABSTRACT

There are multiple methods for determining Vertical Dimension of Occlusion (VDO), but most of them require scientific validation. ***Aim:*** *To study the correlation between mandibular cephalometric measurements and VDO in young Chilean adults with complete dentition and known inclusion criteria, by using modified Knebelman's technique.* ***Materials and Method:*** *The study population consisted of 96 young Chilean adults aged 18 to 35 years. Inclusion criteria were complete natural dentition, bilateral molar support, skeletal class I or mild class II, presence of anterior coupling, and asymptomatic temporomandibular joints. Exclusion criteria were prior or ongoing orthodontic treatment, having undergone orthognathic or other facial surgery, poor oral habits (mouth breathing, or lingual, labial or object interposition), severe dental crowding (IOTN score > 2), too much beard and/or soft tissue under the chin. Anthropometric measurements were taken with a modified digital vernier caliper. Mandibular cephalometric measurements were taken with the QuickCeph 2000 software on digital lateral cephalometric x-rays. All anthropometric and cephalometric measurements were taken by one operator. Based on the mandibular cephalometric measurements with the highest correlation, a mathematical model was proposed to predict the VDO [VDO' = (XAEO-STF)*0.3 + (R3R4 dist.)0.5 + (Go-Ar dist.)-0.3 + (Ar-Po Mand.Depth.)*0.4 – 8], whose predictive capacity will be tested.* ***Results:*** *The three cephalometric measurements with highest correlation with VDO were selected. The resulting predictive model correlated significantly with actual VDO (r= 0.77), in addition to having significant correlation values according to the Björk-Jarabak facial biotypes.* ***Conclusions:*** *The proposed mathematical model demonstrated a strong correlation with the Vertical Dimension of Occlusion. It is a reliable method, uninfluenced by the patient's sex or biotype, and is useful for restoring the VDO within a physiological range close to its original state.*

Keywords: *vertical dimension of occlusion - cephalometry - mandibular size - modified Knebelman technique - predictive model.*

Tamaño mandibular como variable predictora de la dimensión vertical oclusal a partir del análisis cefalométrico

RESUMEN

Existen múltiples métodos para determinar la Dimensión Vertical de Oclusión (DVO), pero la mayoría requiere de validación científica. ***Objetivo:*** *Estudiar la correlación entre mediciones cefalométricas mandibulares y la DVO en adultos jóvenes chilenos con dentición completa y criterios de inclusión conocidos, utilizando la Técnica de Knebelman modificada.* ***Materiales y Método:*** *La población de estudio es de 96 jóvenes chilenos de 18 a 35 años. Criterios de inclusión: dentición natural completa, soporte molar bilateral, clase esqueletal I o clase II suave, presencia de acople anterior y articulaciones temporomandibulares asintomáticas. Criterios de exclusión: aquellos con tratamiento de ortodoncia previa o en curso, sometidos a cirugía ortognática u otra cirugía facial, con malos hábitos orales (respiración bucal, interposición lingual, labial y de objetos), presencia de apiñamiento dentario severo (índice IOTN> 2), cantidad excesiva de barba y/o tejido blando bajo el mentón. Se realizaron mediciones antropométricas con un pié de metro digital modificado y cefalométricas mandibulares mediante el software QuickCeph 2000 en telerradiografías de perfil digitales. Tanto las mediciones antropométricas como cefalométricas fueron realizadas por un mismo operador. A partir de las mediciones cefalométricas mandibulares con mayor correlación, se plantea un modelo matemático para predecir la DVO [DVO'= (XAEO-STF)*0.3 + (dist.R3R4)*0.5 + (dist.Go-Ar)*-0.3 + (Depth.Mand. Ar-Po)*0.4 – 8], cuya capacidad predictiva será puesta a prueba.* ***Resultados:*** *Se seleccionaron las tres medidas cefalométricas con mayor correlación con la DVO. El modelo predictivo resultante correlacionó significativamente con la DVO real (r= 0.77) y además obteniendo valores de correlación significativos según los biotipos faciales de Björk-Jarabak.* ***Conclusiones:*** *El modelo matemático planteado demostró una buena correlación con la Dimensión Vertical de Oclusión. Es un método fiable, no influenciado por el sexo o biotipo del paciente y útil para restaurar la DVO dentro de un rango fisiológico cercano al original.*

Palabras clave: *dimensión vertical de oclusión - cefalometría - tamaño mandibular - técnica de Knebelman modificada - modelo predictivo.*

To cite:
Gárate-Silva OE. Mandibular size as a predictor of vertical dimension of occlusion based on cephalometric analysis. Acta Odontol Latinoam. 2024 Dec. 30;37(3):237-245. https://doi.org/10.54589/aol.37/3/237

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Received: April 2024
Accepted: December 2024.

CLINICAL IMPLICATIONS

Enables simple, reliable determination of VDO, independently of biotype, sex or edentulousness, by means of a mathematical equation with 4 variables: one clinical measurement and 3 measurements taken on a lateral cephalometric x-ray.

INTRODUCTION

Determining the Vertical Dimension of Occlusion (VDO) is a basic step in planning prosthetic rehabilitation for an edentulous patient without stable occlusal references. Clinicians should be aware of their skills and limitations upon choosing a method. Goldstein et al. claim that there is a difference, philosophically speaking, between restoring and increasing VDO[1]. There is currently vast evidence supporting the need to restore VDO in patients who have lost occlusal landmarks or have severe dental wear, and many successful outcomes have been achieved[2]. Calamita et al. (2019) concluded that VDO can be considered a dimension that is not immutable over time, and can therefore be found within a range of physiological tolerance[3]. Lassman et al. note that there is no scientific evidence to support any direct association between altering the VDO and the development of temporomandibular disorders[4].

Batra says that although there are multiple tools and/or methods for determining VDO, most of them lack solid supporting scientific evidence[5]. Moreover, most current methods for determining VDO share a characteristic, since they all use the Postural Vertical Dimension (PVD) variable in some reference. Although there is no solid evidence showing that PVD changes over a person's lifetime, it has been established that it may be compromised due to loss of muscle tone as a result of aging (also related to sarcopenia and loss of muscle function in edentulous patients). As PVD is 3-dimensional, it can be affected by numerous factors, making its use unreliable for determining VDO[3].

A study by Silva et al. uses a craniometric method based on lateral craniometric x-rays, like the current study. Silva et al. propose a VDO predictive model based on cranial height and diameter (glabella-opisthocranion distance), in which a value of 0.702 was found for Pearson's correlation[6].

A well-known method for determining VDO is Knebelman's clinical craniometric method, which determines VDO directly, without the need to consider interocclusal distance or VDP. Knebelman S. Craneometric method for establishing occlusal vertical dimension. 1987. U.S. Patent number No. 4718850. Many studies have analyzed the different variables involved in Knebelman's method with the aim of testing and validating it scientifically. Chou et al. found that Knebelman's method had acceptable reproducibility, but that there were significant differences among the groups studied, and that it had not clearly defined participant exclusion and inclusion criteria[7]. In another study, Morata et al. determined that VDO is variable according to sex and facial biotype; that the most reliable facial measurement on the skin is the left side of the face, where average Pearson's correlation was found to be 0.56, and that when segmented according to biotype (classified using Facial Morphological Index), the highest correlation was found in the mesoprosopic group (r=0.60)[8].

Considering the simplicity of Knebelman's craniometric method, the aim of the current study is to reformulate it methodologically with a few adjustments, in hope of achieving better results for Pearson's correlation, which is an important parameter for comparison with other similar prior studies. Instead of using Knebelman's craniometer, we propose to use a digital vernier caliper, which is more readily available and easier to use. In addition to the measurements proposed by Knebelman, we propose some cephalometric references known to be stable and independent of edentulism. Finally, we evaluate the correlation between these measurements and the original VDO of the study subjects, with stable occlusal references and known inclusion criteria. The research hypothesis is that the variables associated to mandibular size (determined by facial biotype) could improve the predictive capacity of Knebelman's craniometric method, expressed as a function of the Pearson's correlation obtained, thereby enabling prediction of VDO by means of a mathematical equation[9].

MATERIALS AND METHOD

Sample selection

The sample consisted of 96 healthy young Chilean adults aged 18 to 35 years (49 male and 47 female), recruited over a period of six months, who were dentistry students at the University of Chile. Inclusion criteria were having complete natural dentition, bilateral molar support, skeletal class I or mild class II (without need for treatment), presence of anterior coupling, temporomandibular joint with normal movement range and no associated symptoms. Exclusion criteria during screening (clinical examination phase) were prior or ongoing orthodontic treatment, prior orthognathic surgery or any other surgery altering facial morphology, poor oral habits (mouth breathing or lingual, labial or objects interposition), severe dental crowding (IOTN score > 2), excessive beard and/or soft tissue under the chin[10].

Informed consent and ethical considerations

Each participant signed and informed consent which had been approved by the Ethics Committee of the School of Dentistry of the University of Chile. Digital lateral cephalometric radiographs followed rigorous standards for protection against radiation.

Facial dimension measurements

An ordinary vernier caliper modified with a fixed metal extension on one of the arms (Fig. 1) was used to measure the distance in millimeters between the anthropometric points equivalent to those in Knebelman's Craniometric Method described in the method proposed by Gaete et al.[11], as follows: Subnasale (Sn') to Mentum (Me'). cutaneous, at Maximal Intercuspation (MIC); and between the landmarks Outer Canthus of the Eye (AEO) – right and left sides with eyes closed – and the Facial Tragus Sulcus (STF). All these measurements were taken on the skin with minimum compression (Fig. 2).

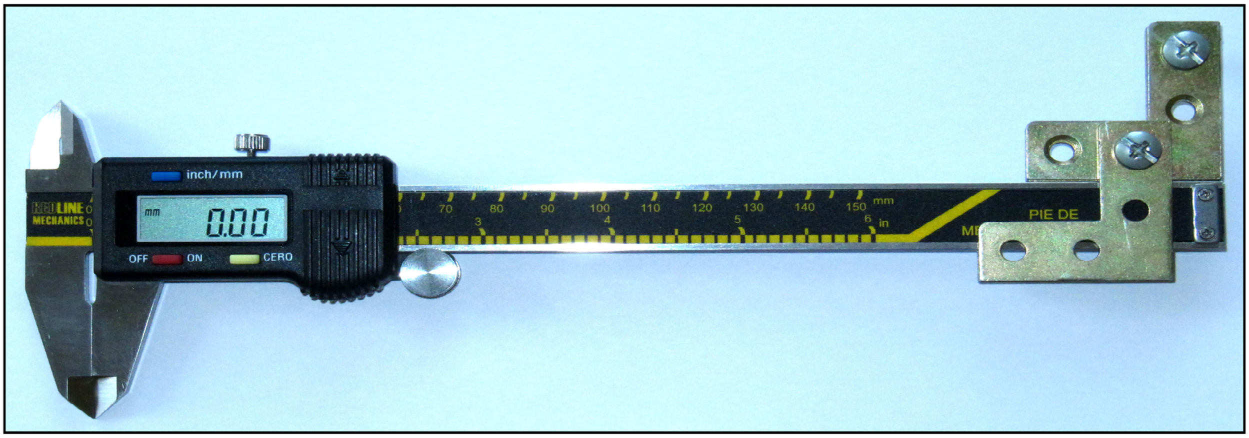

Fig. 1: Modified digital vernier caliper

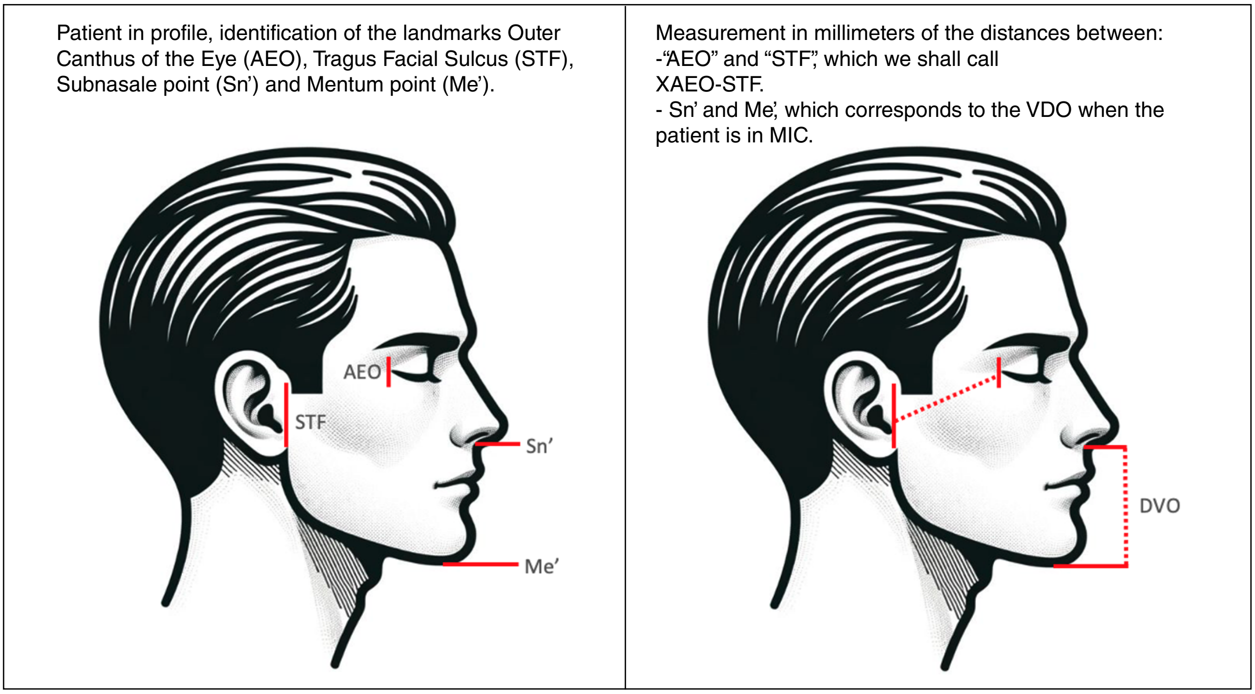

Fig. 2: Modified Knebelman method, references for measurement

All measurements were taken by one operator, with the digital vernier caliper placed at 0.0 each time. To avoid errors in measurements, the procedure was repeated up to three times per measurement so that the values recorded for a measurement would not vary by more than 1mm.

Measurements to assess mandible size

Out of all the types of cephalometric analyses described by different authors, the eight mandibular cephalometric measurements that can be made on a lateral cephalometric x-ray were selected. One operator reproduced the known cephalometric landmarks on each digital cephalometric x-ray using QuickCeph 2000 software.

The following measurements were proposed at the beginning of the study: Gonial Angle (part of Ricketts and Steiner's cephalometric analysis), Mandibular Arc Angle (part of Björk-Jarabak's cephalometric analysis), Gonion-Mentum Distance (part of Ricketts' cephalometric analysis), Distance R1-R2 and Distance R3-R4 (part of VTO analysis), Sigmoid Notch Depth, Articular Distance to Pogonion (part of Ricketts' cephalometric analysis) and Articular Distance to Gonion projected -Go'- (part of Björk-Jarabak's cephalometric analysis) (Fig. 3).

The eight cephalometric measurements taken on the lateral cephalometric radiography were analyzed using Stata 10® software and subjected to Pearson's analysis of correlation and statistical significance ($p < 0.05$ in the T-test) in relation to the VDO variable found for study participants.

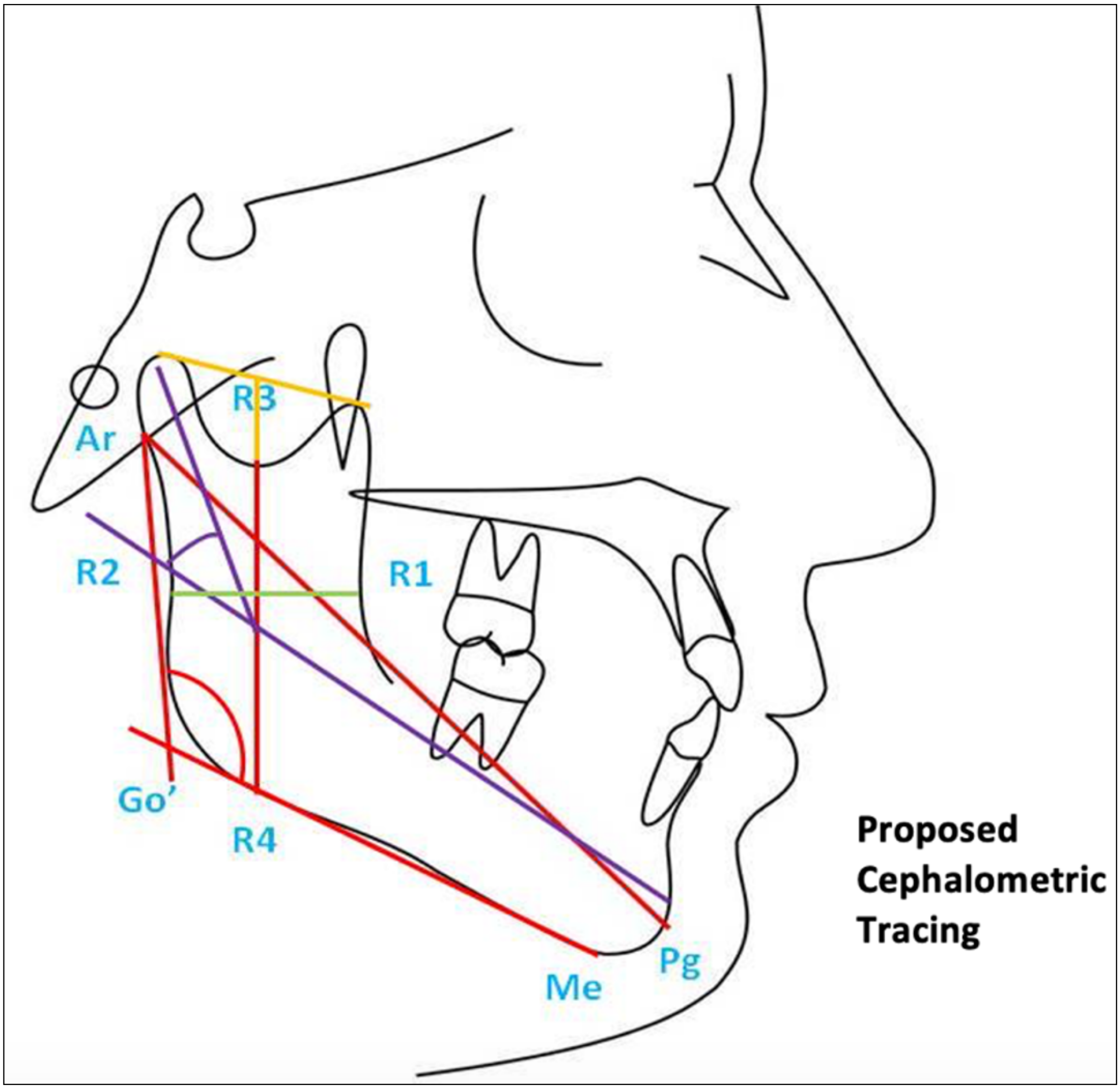

Fig. 3: Initial cephalometric tracing proposed with the landmarks for measuring the suggested variables.

RESULTS

Comparison of the average values in the study group (49 males and 47 females) between VDO and the AEO-STF measurement (average between right and left sides) showed that AEO-STF varied by up to 5.56 mm more than VDO in the study subjects (Table 1).

Table 1: Averages, standard deviation, minimum and maximum values of clinical measurements

Values for total sample

Variable	Average	Standard Deviation	Minimum Value	Maximum Value
VDO (Sn-Me)	69.70	5.88	59.22	84.04
right AEO-STF	75.45	4.88	60.01	86.32
left AEO-STF	75.07	4.72	59.40	86.06

Values of the sample segregated according to sex (Male: M; Female: F)

Variable	Average		Standard Deviation		Minimum Value		Maximum Value	
Sex	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
VDO (Sn-Me)	73.15	66.39	5.38	4.23	59.38	59.22	84.04	74.53
right AEO-STF	77.67	73.33	4.37	4.41	60.33	60.01	86.32	81.60
left AEO-STF	77.13	73.09	4.20	4.36	59.40	63.28	86.06	81.37

The eight cephalometric measurements recorded initially were subject to statistical analysis on Stata 10® software, and any variables with low Pearson's correlation or low statistical significance ($p < 0.05$ in the T-test) in relation to the VDO variable were discarded. Thus, three cephalometric measurements remained for consideration in the final predictive model: Dist.R3-R4, Dist.Ar-Pog, and Dist.Go'-Ar (Fig. 4 and Table 2).

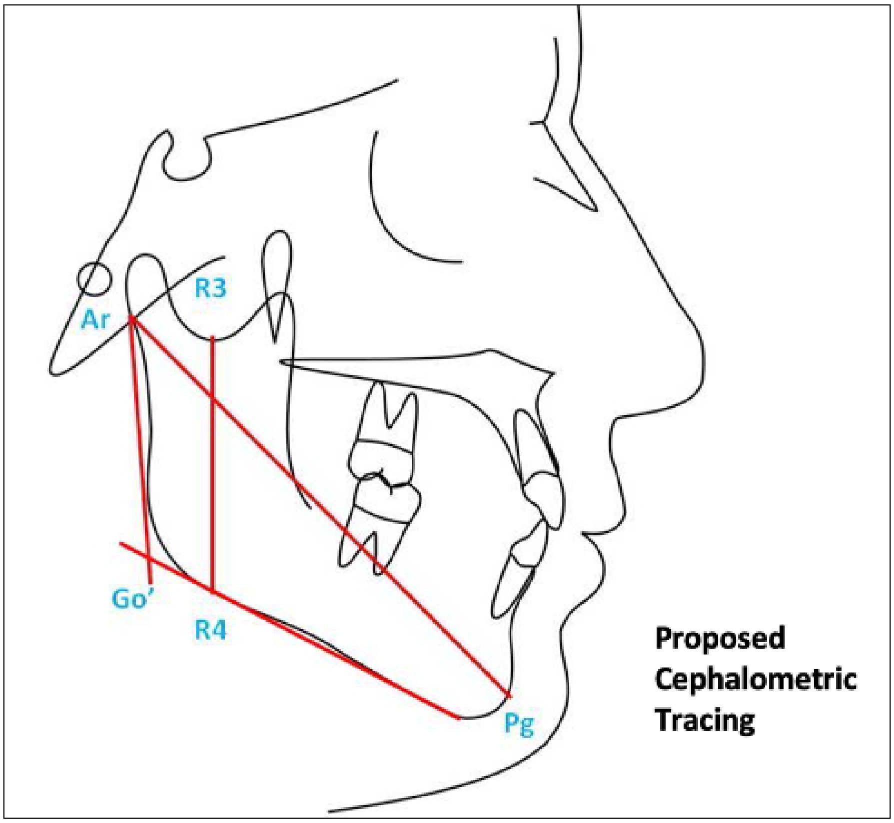

Fig. 4: Final cephalometric tracing with the landmarks for measuring the variables proposed

Table 2: Averages, standard deviation, minimum and maximum values of the selected cephalometric measurements

Values for total sample

Variable	Average	Standard Deviation	Minimum Value	Maximum Value
R3-R4	49.40	4.74	39.68	60.16
Depth. Ar-Pog	105.32	7.18	89.20	123.30
Go'-Ar	48.75	6.31	35.00	71.50

Values of the sample segregated according to sex (Male: M; Female: F)

Variable	Average		Standard Deviation		Minimum Value		Maximum Value	
Sex	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
R3-R4	53.36	46.56	3.77	3.73	44.48	39.68	60.16	54.43
Depth.Ar Pog	110.22	100.63	5.64	5.07	95.60	89.20	123.30	111.9
Go'-Ar	52.18	45.47	6.12	4.52	37.70	35.00	71.50	53.50

After the preliminary analyses, the clinical measurements (XAEO-STF) and cephalometric measurements (Dist.R3-R4, Dist.Ar-Pog, Dist. Go'-Ar) together were subjected to Multiple Linear Regression Analysis with the aim of finding a mathematical model to predict VDO. The following equation was found: [VDO'= (XAEO-STF)*0.3 + (dist.R3R4)*0.5 + (dist.Go-Ar)*-0.3 + (Depth. Mand.Ar-Po)*0.4 – 8].

Pearson's Correlation for the total study population was 0.77 (interpreted as follows: 0.1 to 0.3 low correlation, 0.3 to 0.5 medium correlation, and 0.5 to 1 high Correlation:)[12]. A subsequent step investigated the correlation between the VDO found using the predictive model and the original VDO (Sn-Me), but segregating the subjects according to Björk-Jarabak, biotypes, finding the following: Hyperdivergent Biotype: R-squared 0.8473 and Pearson's Correlation 0.92 (Fig. 5), Normodivergent Biotype: R-squared 0.8917 and Pearson's Correlation 0.94 (Fig. 6), Hypodivergent Biotype: R-squared 0.5560 and Pearson's Correlation 0.74 (Fig. 7).

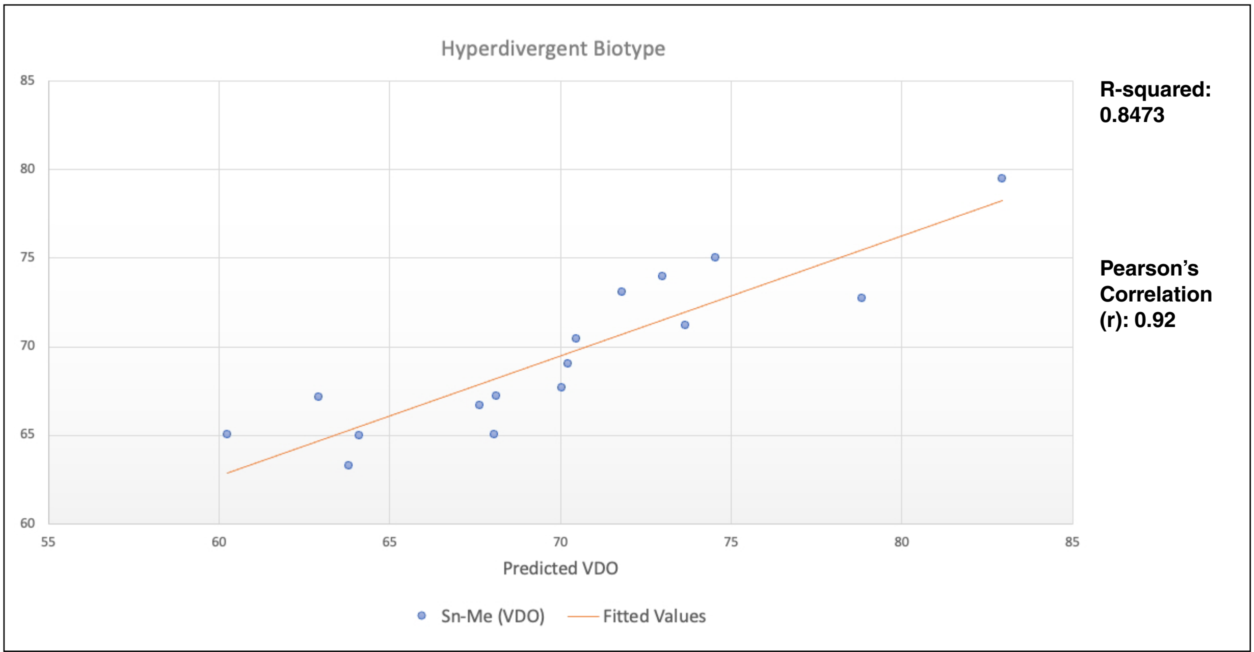

Fig. 5: Dispersion of the variable predicted Vertical Dimension of Occlusion (Predicted VDO) in relation to the variable original VDO in Hyperdivergent biotype

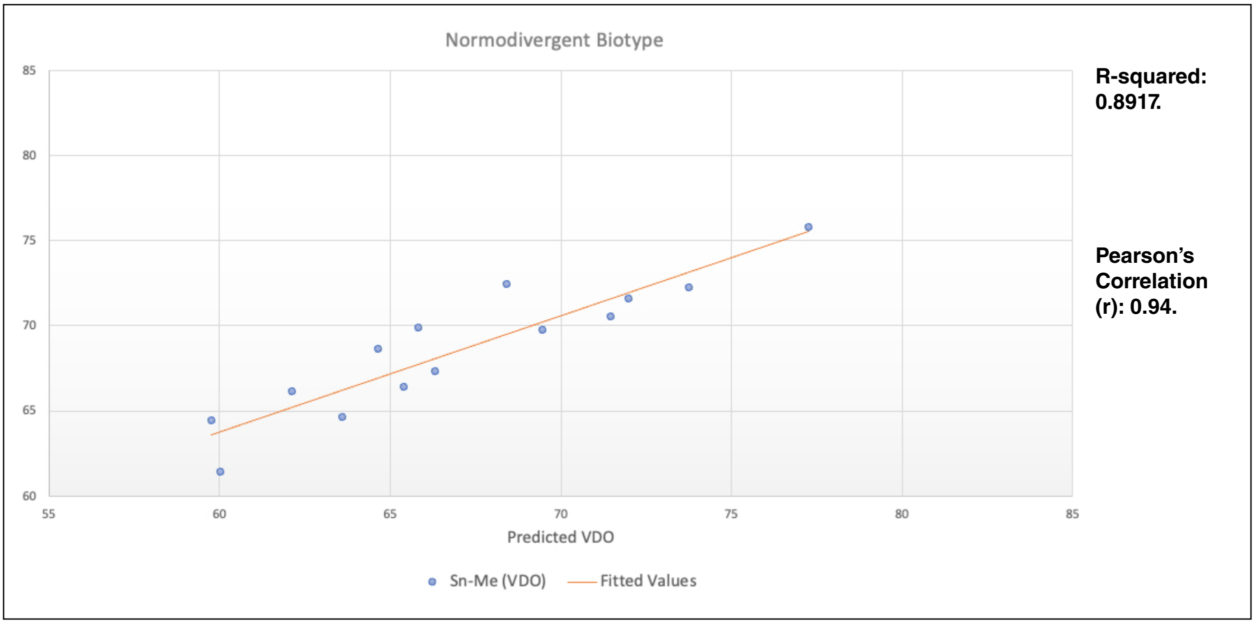

Fig. 6: Dispersion of the variable ***predicted Vertical Dimension of Occlusion*** *(Predicted VDO) in relation to the variable* ***original VDO*** *in Normodivergent biotype*

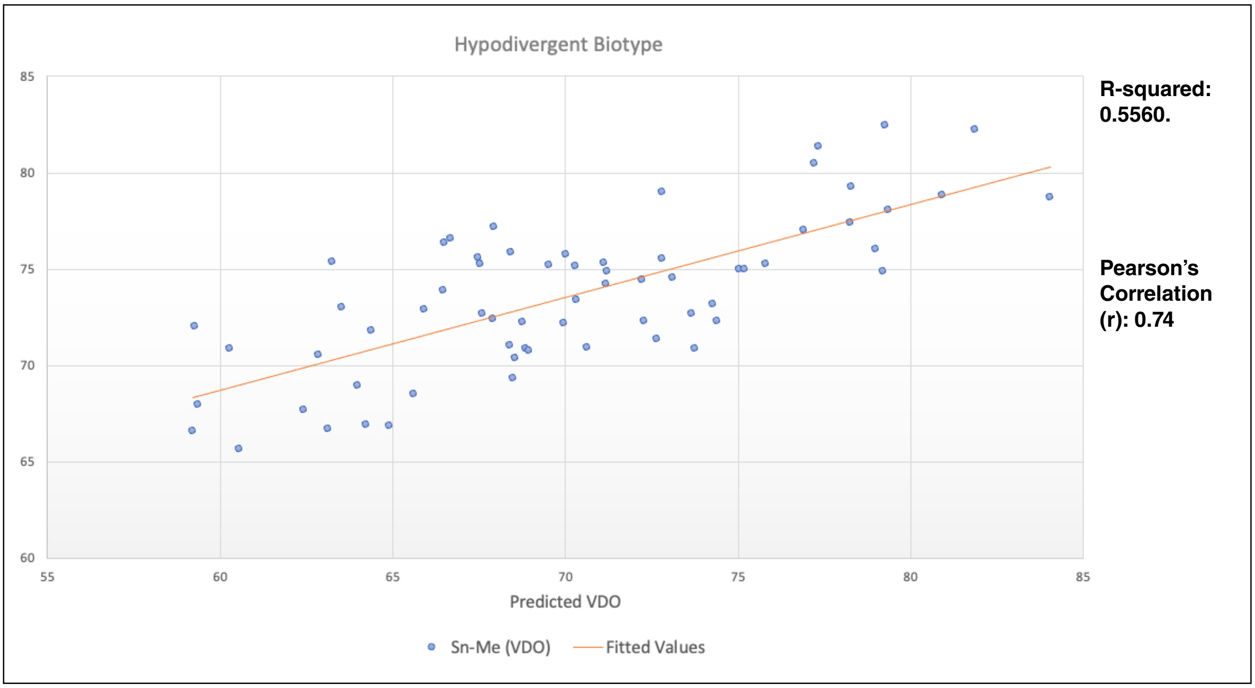

Fig. 7: Dispersion of the variable predicted Vertical Dimension of Occlusion (Predicted VDO) in relation to the variable original VDO in Hypodivergent biotype

DISCUSSION

Our initial parameter for comparison corresponds to Knebelman's Craniometric Method, whose practicality and simplicity make it attractive to use. However, determining Vertical Dimension of Occlusion involves more than simply subtracting an arbitrary predetermined value from the distance between the eye and the ear (AEO-STF), as originally proposed by Knebelman. The current study proposes an integrated method for determining VDO which includes both clinical and cephalometric information, and would be applicable to all patients, regardless of sex, biotype and edentulousness.

Based on the results of the current study, Knebelman's proposition can be contrasted empirically. Knebelman's method states that the distance from cutaneous Subnasale (Sn') to cutaneous Mentum (Me'), which would correspond to the Vertical Dimension of Occlusion, is 3 to 5 mm shorter than the distance from the anterior wall of the external auditory canal to the lateral edge of the orbit cavity (equivalent to the distance from Outer Canthus of the Eye to Tragus Facial Sulcus in our method) because the difference in the average values found is 5.56 mm (Table 1). Moreover, analysis of the data in the report by Morata et al., and comparison of its average anthropometric values to the VDO recorded for its participants shows a difference of 2.18 mm, which is outside the range proposed by Knebelman. The study by Chou et al. on Knebelman's method says that determining the Vertical Dimension of Occlusion requires consideration of other factors that influence its final value[7]. It was this statement that led us to seek other variables, beyond the eye-ear distance preliminarily proposed by Knebelman. The statistical analysis in the article by Chou et al. does not provide the average values found, but only the correlation coefficients for each group analyzed, so it is not possible to compare it to the original Knebelman method as done in our study. In general terms, the correlation values in our study (R-squared and Pearson's r) are higher than those reported by Chou et al. (in which the highest value was only in the group "White Woman", with R-squared 0.76, while the in the others, the values were 0.56, 0.41 and 0.36), and than those reported by Morata et al.[8] (in which average Pearson correlation value was 0.56 and the highest correlation value [0.60] corresponded to the mesoprosopic group).

With the aim of predicting VDO based on cephalometric landmarks, Silva et al. proposed a model based on cranial height and diameter (Dist. Glabella-Opisthocranion), which informs a value of 0.702 for Pearson's correlation[6]. In this case too, our study found higher values for Pearson's correlation, and is therefore a better predictor in mathematical terms[11].

Since in the current study, the values of the clinical measurements for right and left AEO-STF are statistically very similar (Table 1), and considering future clinical use of this method, it is concluded that the measurement of either the right side or the left side can be used equally.

In a subsequent step, all the parameters in this study were subjected to a multivariate analysis with the aim of determining the degree of influence of the variables on the determination of the Subnasale-Mentum measurement (Sn-Me or VDO). In this case, Multiple Linear Regression analysis was used on the 4 variables: Average (right and left sides) of the Distance Outer Canthus of the Eye to Tragus Facial Sulcus (XAEO-STF), Distance R3-R4, Distance Go-Ar, and Distance Ar-Pog (Depth. Mand.) as a function of the measurement Sn'-Me' (or VDO). The results of the analysis show that all the proposed predictive factors explain 58.6 % of the variable Sn-Mn (R-squared 0.5860), with Pearson's correlation coefficient (r) 0.77. This implies a higher value than those described in previous studies (cutaneous distance Sn-Me) (Fig. 5).

Based on the data obtained, we propose a method to determine a reliable VDO, individualized for each patient, with a higher degree of certainty than its predecessors. Although there are significant differences in the magnitude of the measurements according to sex and for each study variable (Tables 1 and 2), we do not propose to calculate VDO differently for each group. The mathematical model is regulated implicitly and through the measurements themselves, because the cephalometric and facial variables implicitly include these variations, with the measurements in each individual corresponding to one another proportionally. Thus, calculated VDO will be higher for males than for females, because in this study population, the measurements in males are greater in than in females.

Analysis of the model as a predictor of Vertical Dimension of Occlusion upon segregating subjects according to biotype shows high correlation values, particularly for the hyperdivergent (Fig. 6) and normodivergent (Fig. 7) biotypes. Although the hypodivergent biotype (Fig. 8) has a lower Pearson's coefficient than the other biotypes, it is still high. This shows that the proposed model has considerable predictive capacity for Björk-Jarabak facial biotypes.

Finally, our initial hypothesis is proved: there is a high correlation between VDO *predicted* by mandibular size and *actual* VDO, with Pearson's correlation (r) 0.77. In addition, the method has advantages, such as being independent of biotype, being simpler and more reliable than other methods, being easily performed, using an easily available digital vernier caliper, having better predictive values than other methods proposed, and most importantly, being independent of edentulousness (a condition that affects the facial index calculation used by Morata et al. as one of the variables for their VDO predictive model). All this makes the method proposed herein more reliable and advantageous than those described previously in the literature.

CONCLUSIONS

Mandibular size, represented by the cephalometric variables Dist.R3-R4, Dist.Go'-Ar and Depth. Mand.Ar-Pog, correlates well to the variable VDO. These variables are important adjustment factors for Knebelman's method, and improve its precision as a predictor for determining VDO.

Statistical analysis of the predictive model created [DVO'= (XAEO-STF)*0.3 + (dist.R3R4)*0.5 + (dist.Go-Ar)*-0.3 + (Depth.Mand.Ar-Po)*0.4 – 8] found a value of 0.77 for Pearson's correlation (r), which is considered significant and is one of the highest reported in the literature.

It is worth highlighting that this method is independent of patient sex and biotype, and most importantly, that the cephalometric landmarks and measurements of the mandible and the facial reference magnitudes for this mathematical VDO predictor model do not vary with edentulism, providing reliability to both the method and the result that can be obtained with the equation. Thus, with a high degree of certainty, this method could be used to predict VDO in completely edentulous patients or patients with unstable occlusal references undergoing oral rehabilitation, enabling restitution of the VDO within the range of physiological tolerance and even very close to the original.

CONFLICT INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

FUNDING

None.

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